School Bus Emissions Study

SAE Paper 2003-01-1381
Plus Cancer Potency Analysis

9th Diesel Engine Emission Reduction Conference
Newport, Rhode Island
August 24-28, 2003

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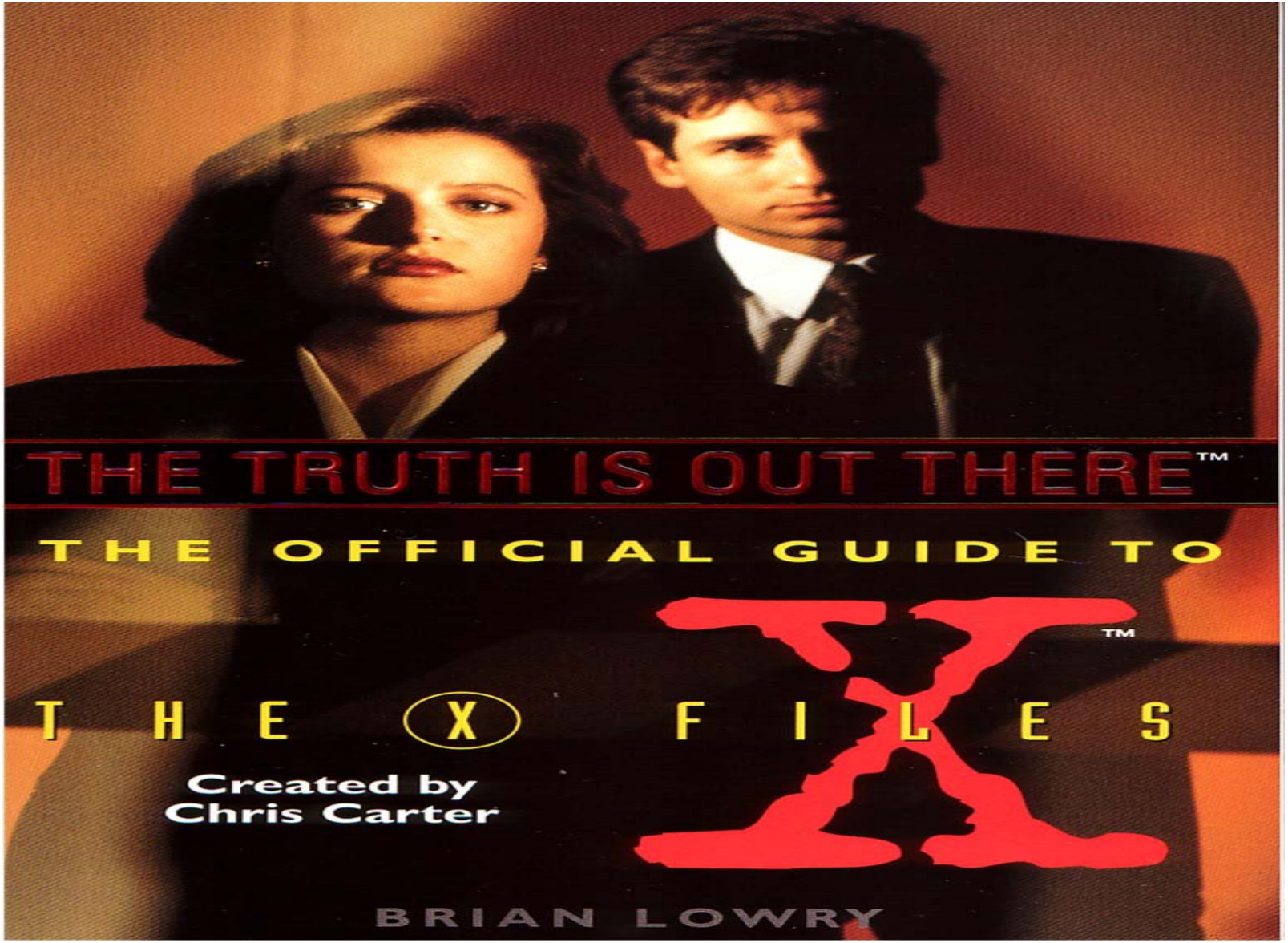
Acknowledgements

- Southwest Research Institute
  - –Terry Ullman
  - –Lawrence Smith
  - –Joseph Anthony
- ConocoPhillips
  - –Charles R. Clark
  - –Joe Kaufman
  - –Kenneth Wright

Study Rationale

- Determine the validity of CARB's claim that there are 41 TACs associated with current diesel exhaust.
- Determine the validity of the claim that natural gas school buses emit fewer toxics than low emitting diesel buses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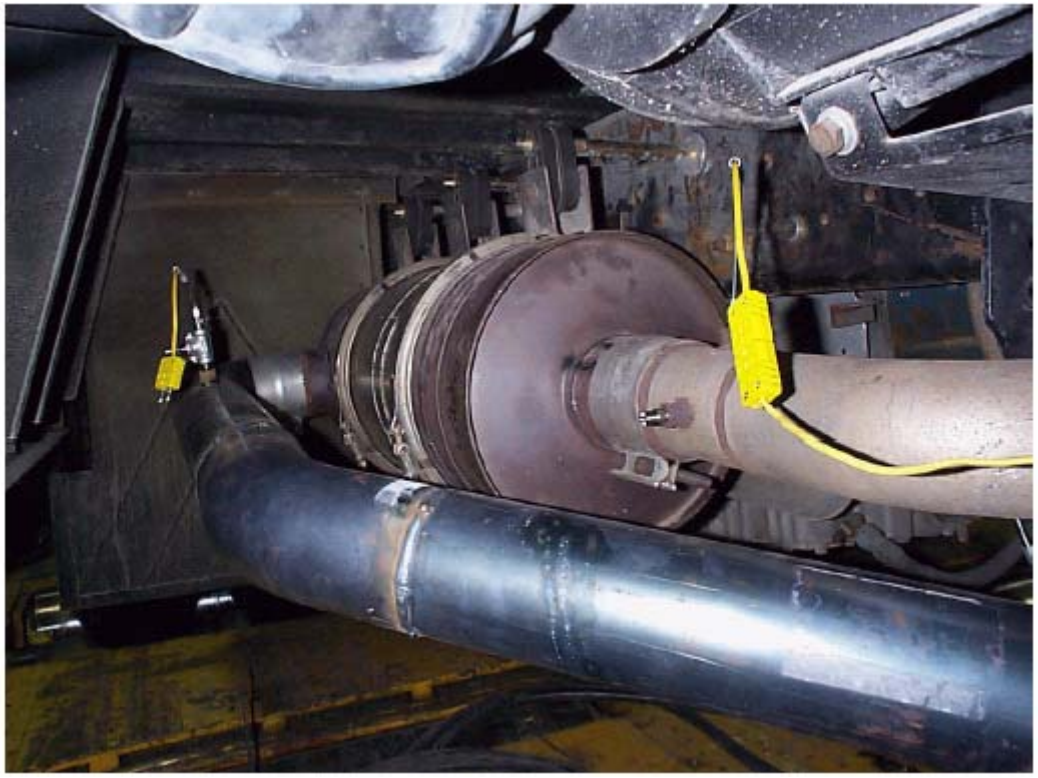
Study Objectives

- Evaluate school buses currently in use
- Compare three engine configurations: conventional diesel (CD), low-emitting diesel (LED), and compressed natural gas (CNG)
- Use a chassis dynamometer, real world test cycle
- Look at regulated emissions and over 300 chemicals
- Compare toxic potency weighted emissions

Diesel School Bus

- 1998 American Transport Chassis
- 2001 International 8.7 L Engine
- Used for conventional & low emitting diesel (LED) configurations
- Changes for conventional diesel configuration:
  - Remove Engelhard DPF
  - Reset low NOx ECM

Engelhard Catalyzed Diesel Particulate Filter for Low Emitting Diesel



CNG School Bus

- 2000 Blue Bird Chassis
- 2000 John Deere 8.1 L Engine
- No aftertreatment
- Assumed same test weight and road load

Why no aftertreatment on CNG Bus?

- Unable to find CNG school bus of the required configuration equipped with aftertreatment. None being purchased.
- SCAQMD Rule 1195 favors the purchase CNG buses without aftertreatment over low emitting diesel

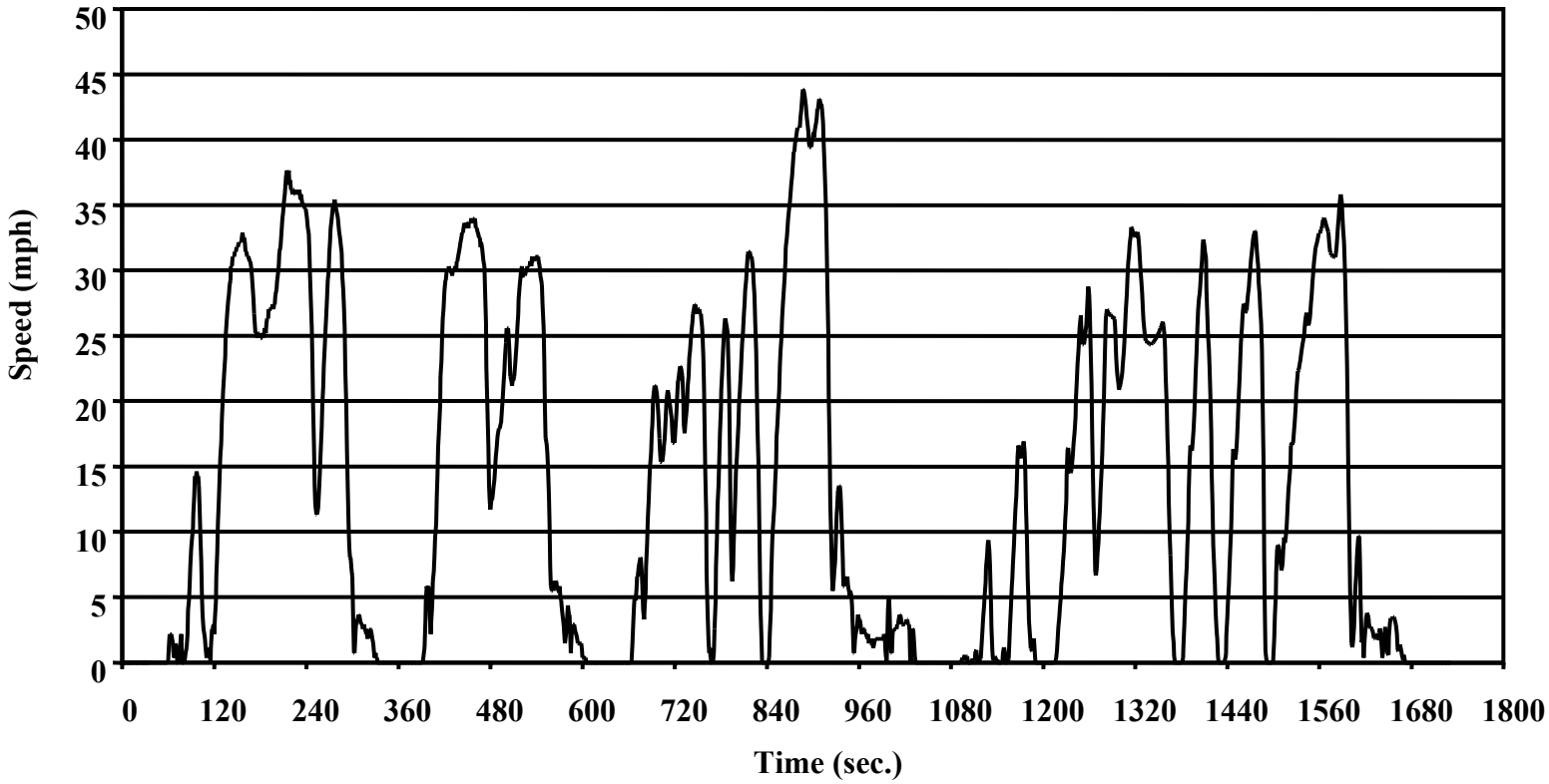
Diesel Fuel

	Ultra-Low Sulfur	Conventional
Sulfur, ppm	14	371
Aromatics, wt%	30.9	33.1
PNAs, wt%	7.6	13.3
Cetane Number	47.7	47.5

CNG Fuel Composition

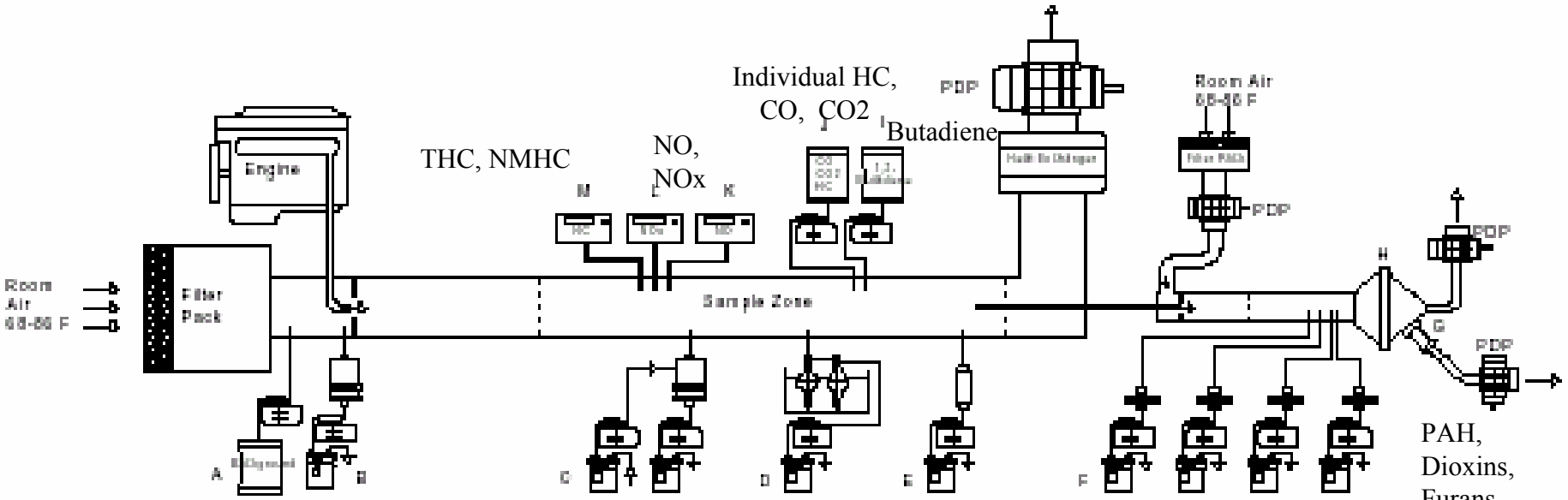
Component	Mole %
Methane	90.21
Ethane	4.11
Ethylene	0.10
Propane	2.11
Nitrogen	3.47
Heating value (BTU/ft^3)	1039
Methane Number (CARB)	88.1

City Suburban Heavy Vehicle Cycle

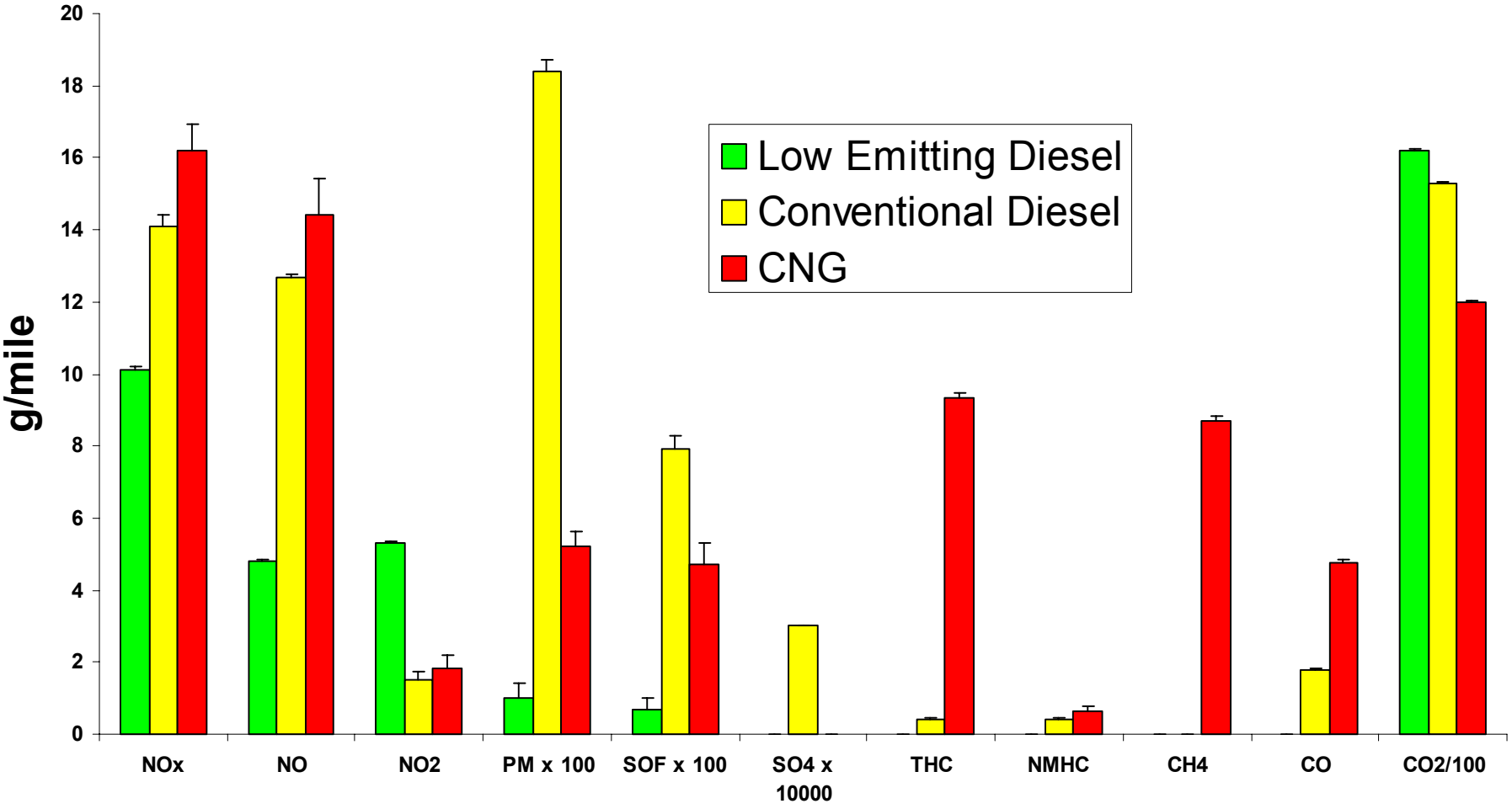


- Three tests for each configuration with three consecutive cycles per test

Sample Collection



Air Quality Emissions



Engine Certification Data

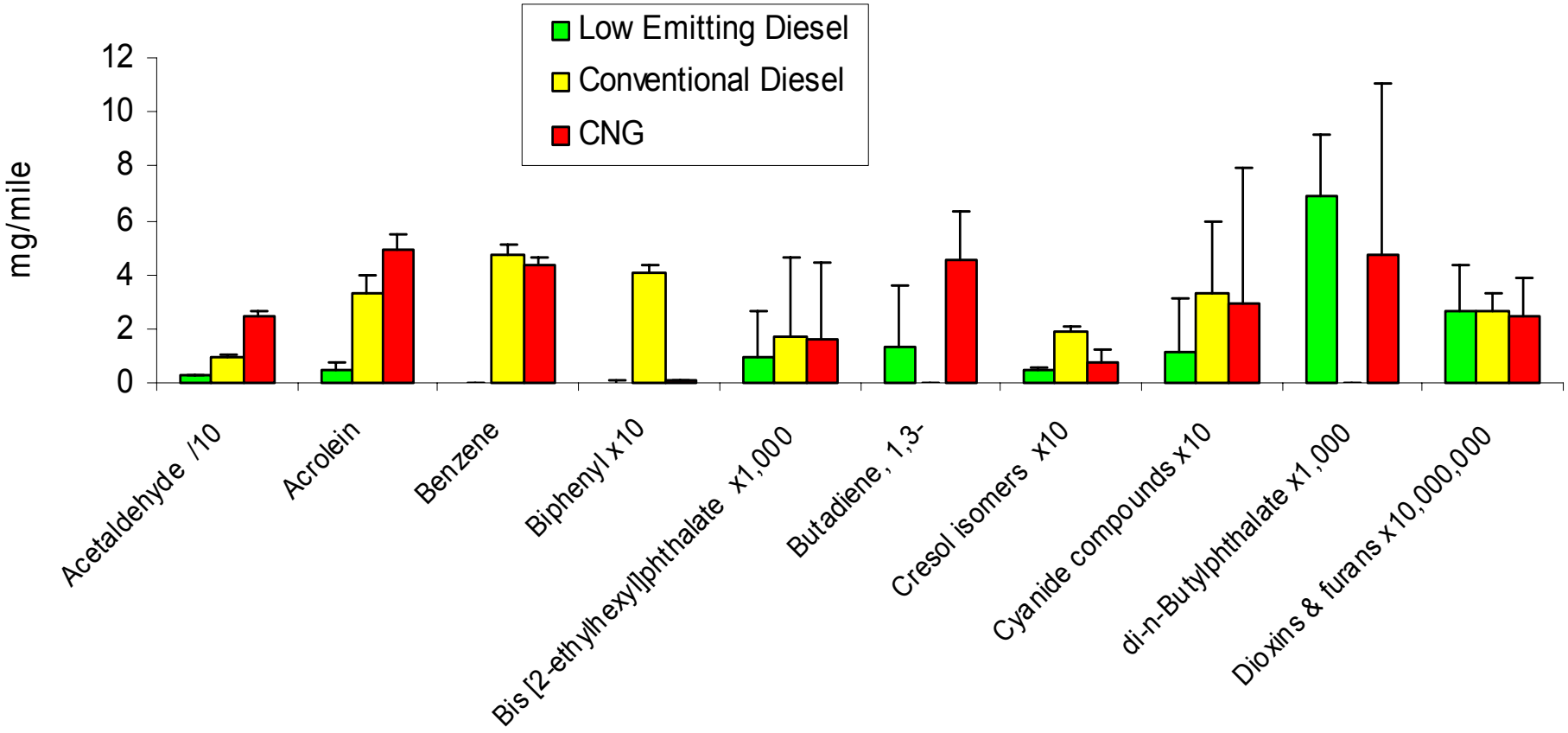
	Low Emitting Diesel	Conventional Diesel	CNG
NOx (g/hp-hr)	3.0	3.9	2.6
PM (g/hp-hr)	0.01	0.09	0.05

- CNG's high NOx emission surprising given its low NOx certification.

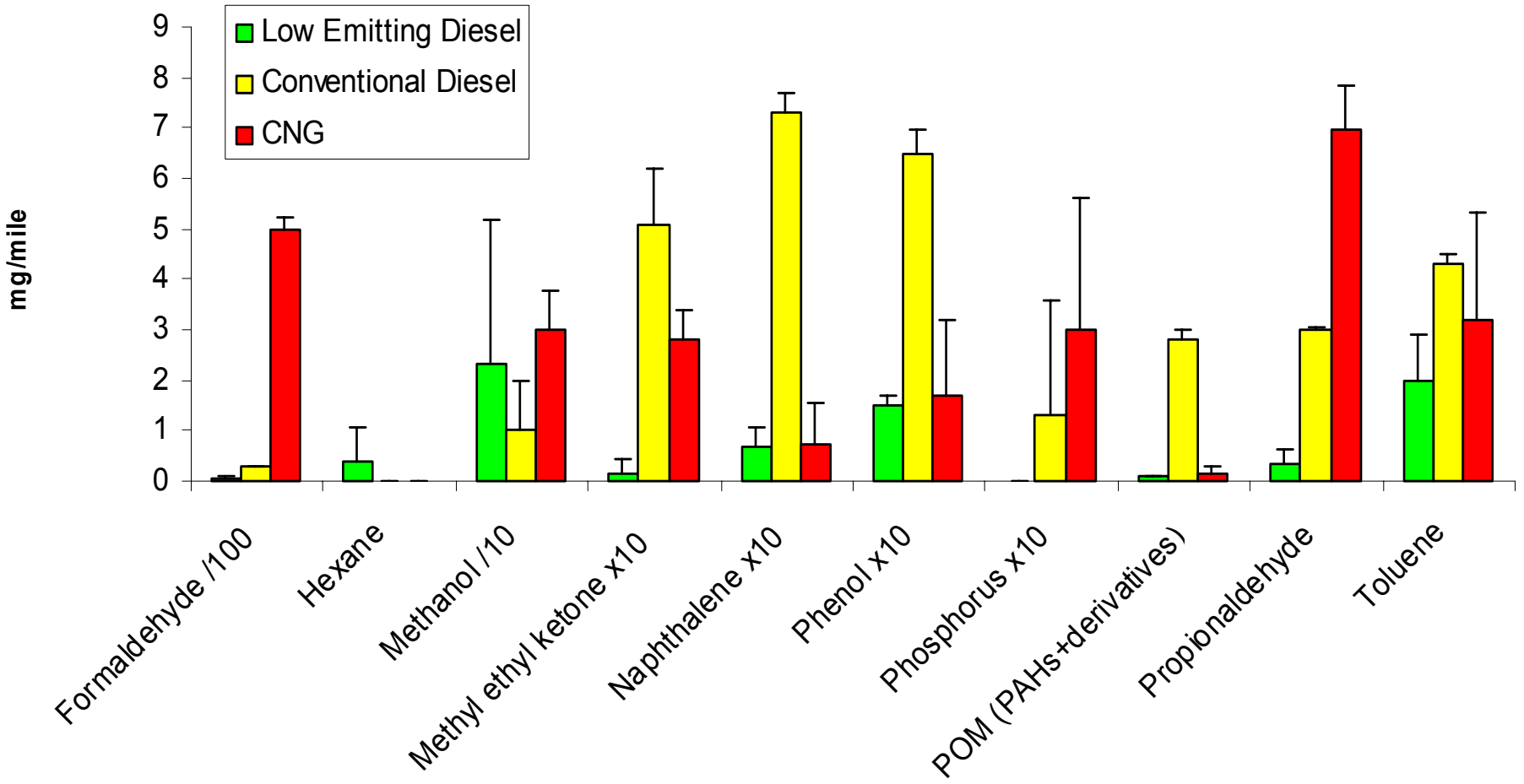
21 Toxic Air Contaminants Were Not Found

- Aniline
- Antimony compounds
- Arsenic
- Beryllium compounds
- Cadmium
- Chlorine (chloride)
- Chlorobenzene and derivatives
- Chromium compounds
- Cobalt compounds
- Ethylbenzene
- Inorganic lead
- Manganese
- Mercury
- 4-Nitrobiphenyl
- Nickel
- Selenium
- Styrene
- Xylene isomers and mixtures
- o-Xylenes
- p-Xylenes
- m-Xylenes

Toxic Air Contaminants (TACs)



Toxic Air Contaminants (continued)



TACs Statistically Same Across All Three Engine Configurations

1) Bis[2-ethylhexyl]phthalate
2) Cyanide compounds
3) Total Dioxins and Furans
4) Hexane
5) Phosphorus

TACs Statistically Same Between LED and CNG

1) Biphenyl
2) 1,3-Butadiene
3) Cresol isomers
4) Di-n-butylphthalate
5) Methanol
6) Naphthalene
7) Phenol
8) Polycyclic Organic Matter (PAH+derivatives)
9) Toluene

TACs Where CNG is Statistically Higher than LED

1) Acetaldehyde
2) Acrolein
3) Benzene
4) Formaldehyde
5) Methyl Ethyl Ketone
6) Propionaldehyde

TACs Where LED is Statistically Higher than CNG

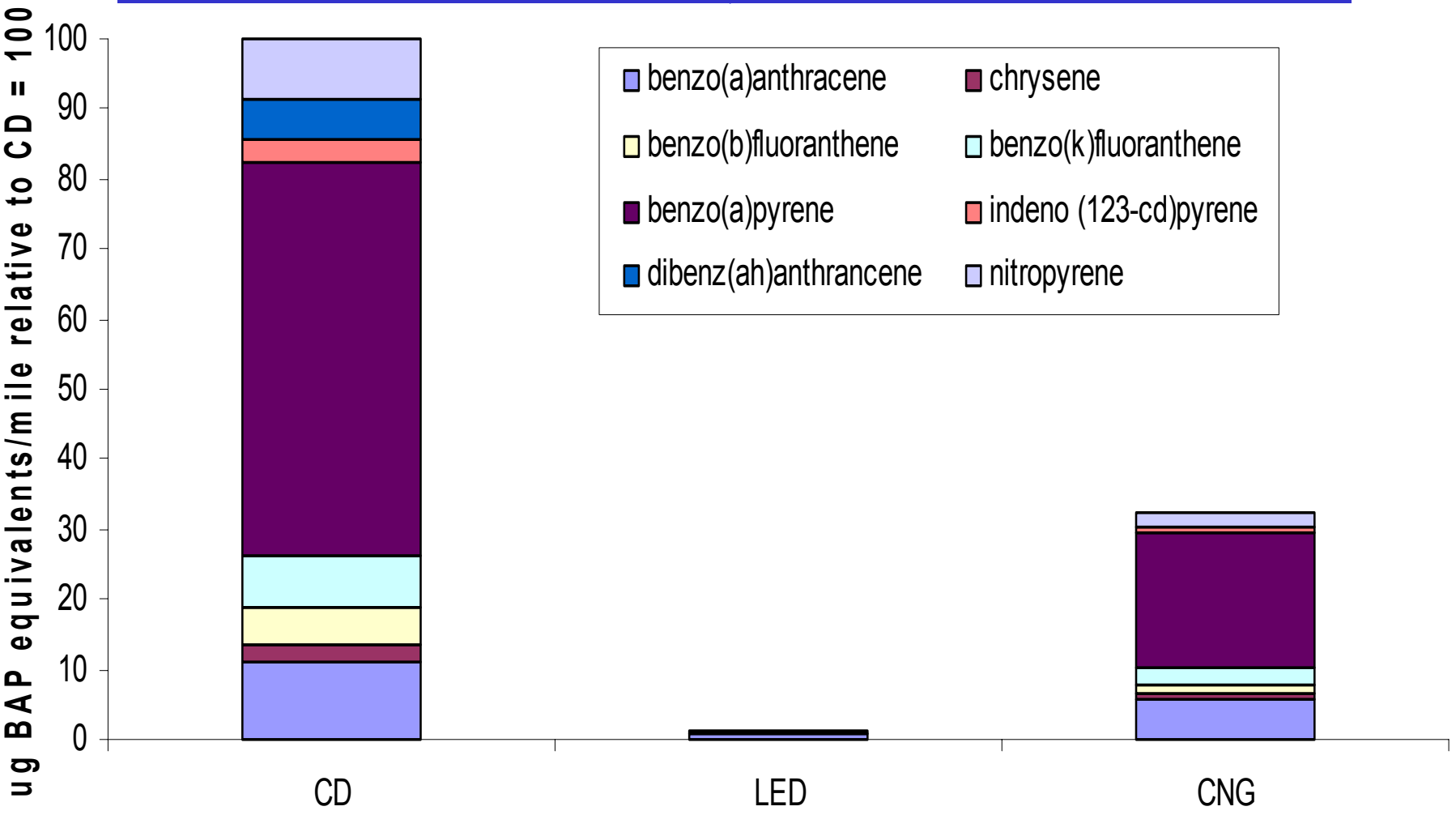
Statistical Ranking Where Only CD and CNG Emissions Differ

	Lower	Higher
Biphenyl	**CNG**	**CD**
1,3-Butadiene	**CD**	**CNG**
Cresol isomers	**CNG**	**CD**
Methanol	**CD**	**CNG**
Naphthalene	**CNG**	**CD**
Phenol	**CNG**	**CD**
POM (PAH+derv.)	**CNG**	**CD**

"Concentrate on what cannot lie. The evidence..." -- Gil Grissom

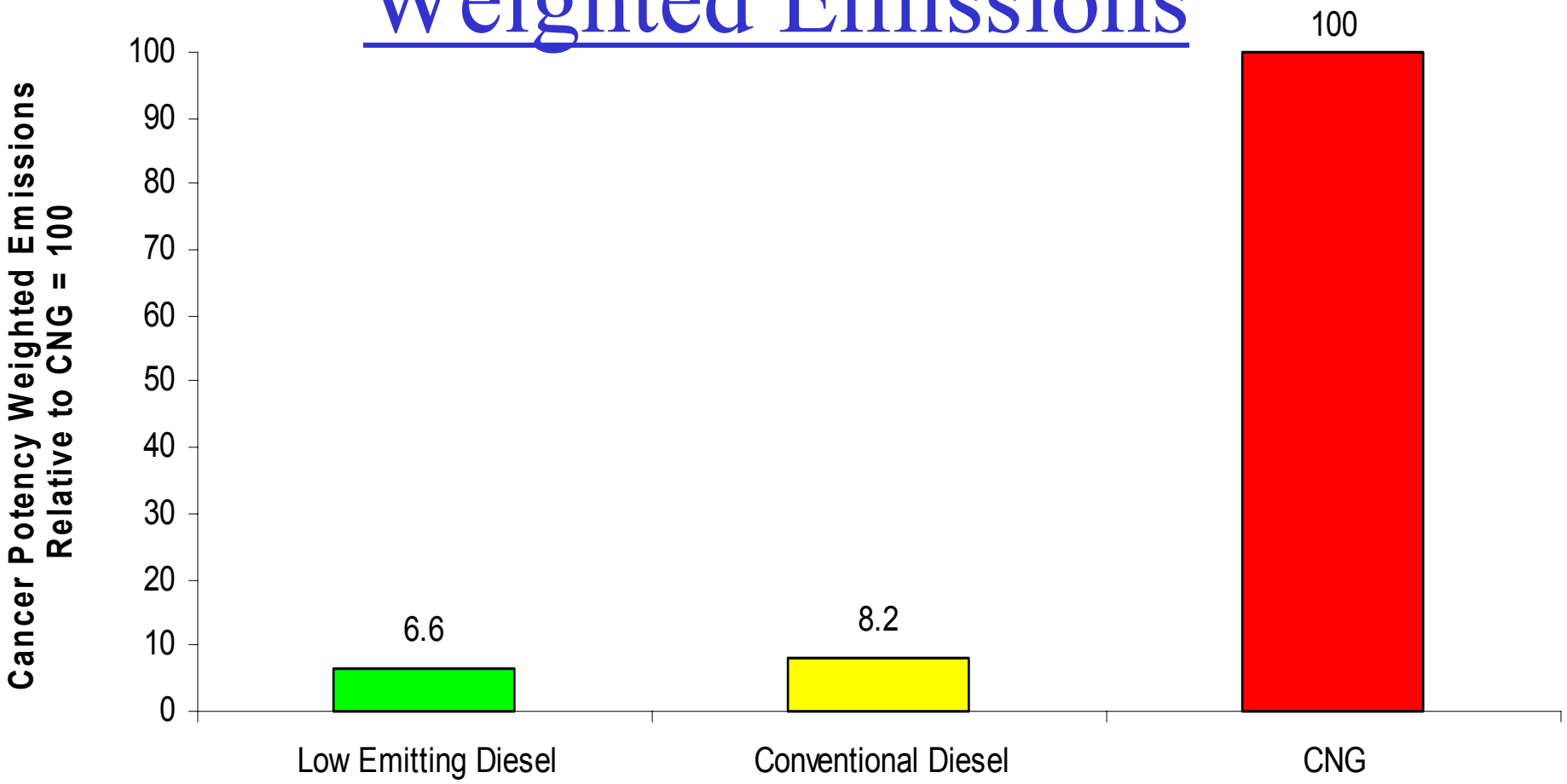
Toxic Potency Weighted Emissions

PAH Emissions: Potency Adjusted & Relative to CD, Individual PAHs



(Calculations adapted from "Draft Staff Report. Procedure for Calculating Toxic Risk Reduction from Vehicle Emissions" SCAQMD, 11/2000)

Relative Cancer Potency Weighted Emissions



$$\text{Cancer Potency Weighted Emissions} = \sum(\text{emission rate}_i)(\text{unit risk factor}_i)$$

(Calculations adapted from "Draft Staff Report. Procedure for Calculating Toxic Risk Reduction from Vehicle Emissions" SCAQMD, 11/2000)

Relative Cancer Potency Weighted Emissions Details

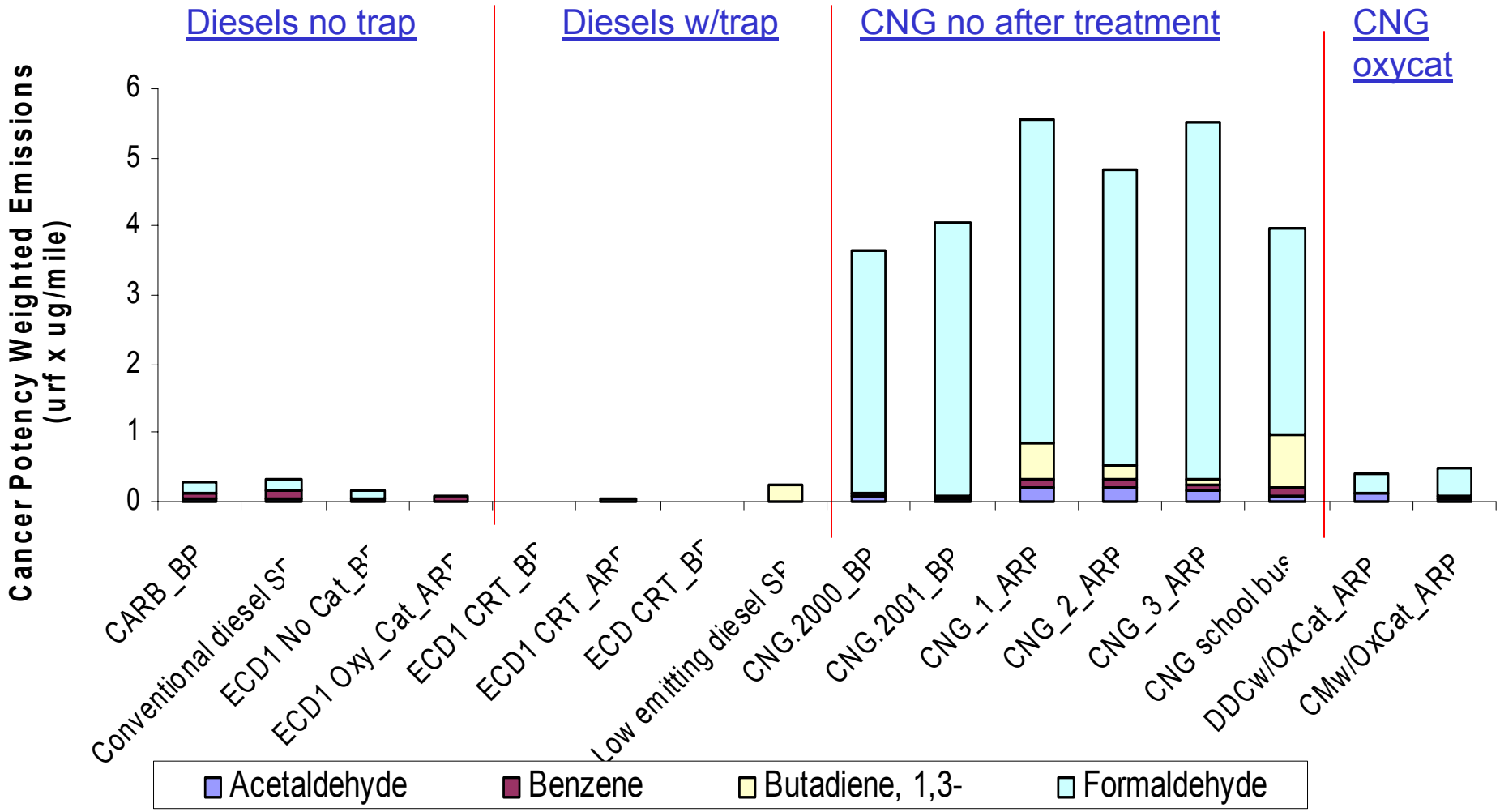
	Low Emitting Diesel	Conventional Diesel	CNG
Formaldehyde	0.8	4.1	75.8
Butadiene, 1,3-	5.6	0	19.3
Benzene	0	3.4	3.2
Acetaldehyde	0.2	0.6	1.6
Dioxins	0.01	0.004	0.01
PAHs	0.0004	0.03	0.009
DHEP	0.00006	0.0001	0.00001
Total	6.6	8.2	100

(Calculations adapted from "Draft Staff Report. Procedure for Calculating Toxic Risk Reduction from Vehicle Emissions" SCAQMD, 11/2000)

Comparison to Other Recent Studies

- CARB and BP compared diesel and CNG fueled transit buses
- CARB transit bus study
  - CNG w/ and w/o oxidation catalyst
- BP transit bus study
  - Evaluated the effect of different diesel fuels
- Both used several different test cycles, Central Business District reported here. Results similar with other cycles.

Cancer Potency Weighted Emissions: Chemical Species Approach



(Calculations adapted from "Draft Staff Report. Procedure for Calculating Toxic Risk Reduction from Vehicle Emissions" SCAQMD, 11/2000)

Summary

- For 8 of the eleven air quality emissions, low-emitting diesel was lower than CNG
- Of the 41 Toxic Air Contaminants (TACs) identified by CARB to be in diesel exhaust, 21 *were not found*
- Of the 20 TACs found, in no case was CNG lower than the low-emitting diesel
- Conventional diesel had 12 of 20 TACs below or equivalent to CNG
- Potency weighted emissions were higher for CNG

Conclusions

"Do not assume anything, clear your mind must be"

Yoda, Star Wars Episode II

1) Don't assume modern diesel emits 41 toxics!!
2) Don't assume natural gas is less toxic than modern diesel!!